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EFFECT OF REPLACEMENT OF CEMENT BY METAKAOLIN ON THE PROPERTIES OF HIGH PERFORMANCE CONCRETE SUBJECTED TO ACID ATTACK

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ABSTRACT

Metakaolin is a valuable admixture for concrete or cement applications and it is a pozzolanic additive product which can provide many specific features. Amongst the various methods used to improve the durability of concrete, and to achieve high performance concrete, the use of Metakaolin is a relatively new approach.

The present study includes the effect of partial replacement of cement with metakaolin by various percentages (0%, 10%, 15%, 20%, 25% and 30%) on the properties of high strength concrete, when it is subjected to acid (HCL, H_2SO_4) attack. Concrete specimens were casted to find compressive strength and cubes are tested for durability studies with present$H_2SO_4$and HCL of 0.5% and 1% concentrations. Cubes, cylinders and prisms are tested for temperature study with 15% replacement of cement by Metakaolin. The specimens were heated to different temperatures of 100^{o}C, 200^{0}C, 300^{o}C, 400^{0}C and 500^{o}Cfor three different durations of 1, 2 and 3 hours at each temperature. After heat treatment, the specimens were tested for compressive strength, split tensile strength, flexural strength and stress-strain behavior. The results conclude that the use of Metakaolin Concrete (MKC) has improved the performance of concrete under various conditions.

KEYWORDS: Metakaolin, High Strength Concrete, Temperatures and Acidic Medium

INTRODUCTION

High performance concrete (HPC) has been widely used in recent years, not only for its increased compressive strength, improved durability and economic benefits, but also for its positive impact on the environment. Out of some available industrial wastes which are used in concrete, Metakaolin is one of the supplementary cementetious material (SCM). Metakaolin is a high quality pozzolanic material, which is blended with Portland cement in order to improve the strength and durability of concrete and mortars. Metakaolin removes chemically reactive calcium hydroxide from the hardened concrete. Metakaolin is a white pozzolan made by heating kaolin clay to a temperature of 600^{0}C-800^{0}Crange; kaolinite becomes metakaolin, with a two-dimensional order in crystal structure.

METHODOLOGY

Based on the preliminary investigations carried out, the experimental investigation is planned as under.

- To obtain the mix proportions for M80 grade concrete using Erntroy and Shack lock's Empirical graphs.
- To prepare concrete specimens such as cubes (150mm x 150mm x 150mm) for durability studies in laboratory

with 0%, 10%, 15%, 20%, 25% and 30%replacement of OPC with Metakaolin for M80 grade concrete.

- To prepare the concrete specimens such as cubes (150mm x 150mm x 150mm) for compressive strength, cylinders (150mm x 300mm) for split tensile test, prisms (100mm x 100mm x500mm) for flexural strength, cylinders (150mm x 300mm) for stress-strain behavior with 0% and 15% replacement of OPC with Metakaolin for temperature study i.e., for 100°C, 200°C, 300°C, 400°C and 500°C and cure the specimens for 28 days.
- To evaluate the mechanical characteristics of concrete such as compressive strength for cubes, flexural strength for prisms, split tensile strength and stress-strain behavior for cylinders.
- To evaluate compressive strength of cubes those are tested for durability studies with H_2SO_4 and HCL of 0.5% and 1% concentrations.
- To evaluate the temperature studies of MKC at an exposure of100°C, 200°C, 300°C, 400°C and 500°C for 1hr, 2hr and 3hr duration and compare the results.

RESULTS AND DISCUSSIONS

The tests were carried out to obtain compressive strength, split tensile strength, flexural strength and stress-strain curve of M80 grade concrete. The specimens are tested for 28 days for 0%, 10%, 15%, 20%, 25% and 30% replacement of MK for compressive strength and the specimens are tested for 28 days for 0% and 15% replacement of MK for flexural strength, stress-strain curve, split tensile strength. These are presented in graphs which were plotted correspondingly.

In order to understand the behavior of MKC under various exposure conditions like effect of temperature, effect of change in duration of heating, effects due to H_2SO_4 and HCL were studied by conducting the tests for M80 grade MKC and the results were discussed.

In the present experimental work the specimens exposed to temperature undergo physical changes and weight loss. The free moisture content is lost initially, followed by physical adsorption of water.

Compressive Strength

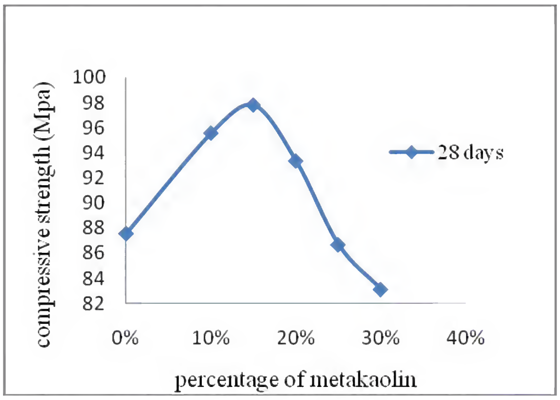

Figure 1: Compressive Strength of Concrete vs % of Metakaolin

From the above figure, it is observed that at 15% replacement of cement with MK, the concrete attains maximum compressive strength when compared with other percentages and when the replacement exceeds 15%, the compressive strength is found to be decreased.

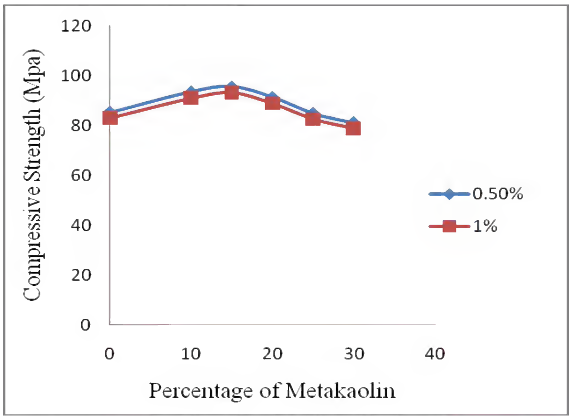

Figure 2: Compressive Strength of Concrete vs % of MK at 0.5% and 1% HCL

From the above Figure, it is observed that at 15% replacement of cement with MK, concrete attains a maximum compressive strength when exposed to 0.5%HCl compared to 1% HCL at the age of 28 days. So as the percentage of HCL concentration increases, the strength decreases.

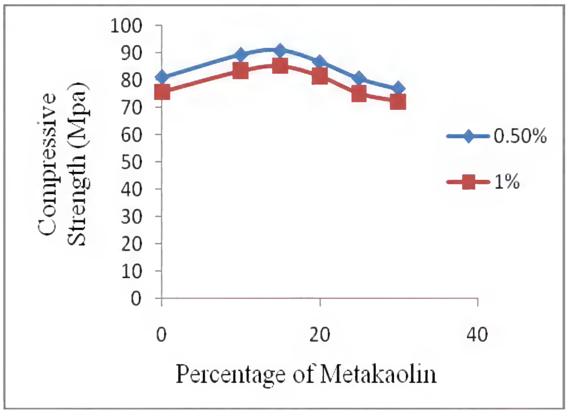

Figure 3: Compressive Strength of Concrete vs % of Metakaolin at 0.5%, 1% H_2SO_4

From the above Figure, it is observed that at 15% replacement of cement with MK, the concrete attains maximum compressive strength when exposed to 0.5%H_2SO_4 compared to 1% H_2SO_4 at the age of 28 days. So as the percentage of H_2SO_4 concentration increases, the strength decreases.

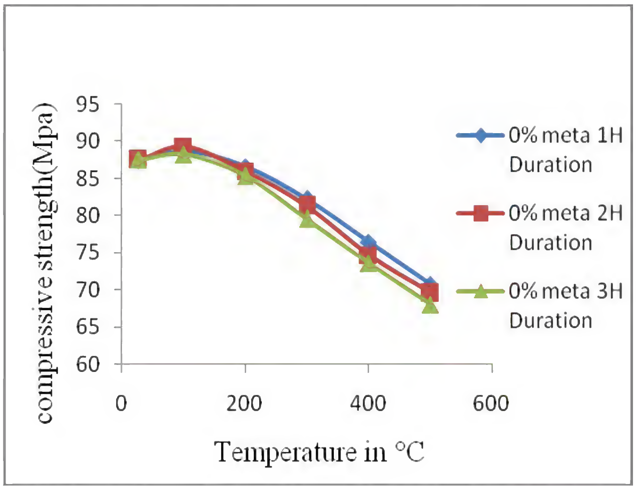

Figure 4: 28 Days Compressive Strength of Concrete (%) vs Exposed Temperature (°C) of 0% MKC

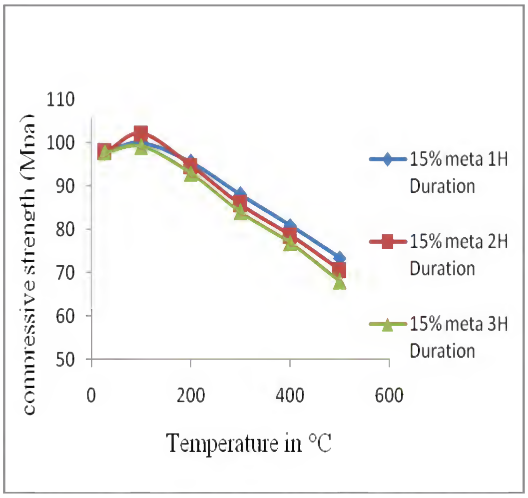

Figure 5: 28 Days Compressive Strength of Concrete (%) vs Exposed Temperature (°C) of 15% MKC

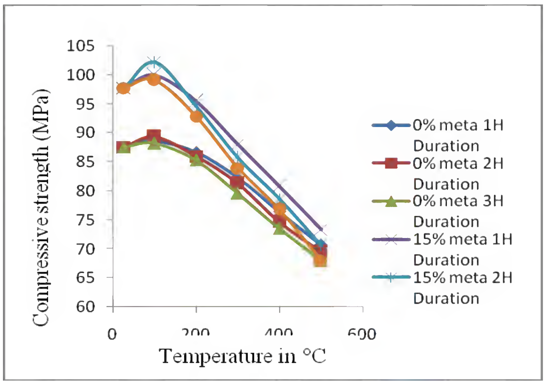

Figure 6: 28 Days Compressive Strength of Concrete (%) vs Exposed Temperature (°C) of 0% and 15% MKC

From the above figures, it is observed that the compressive strength increases at 100°C temperature when compared to the strength obtained at normal room temperature for 0% and 15% replacement of cement with MK. The compressive strength increases from room temperature to 100°C and decreases from 100°C to 200°C and then further decreases at 500°C.

Split Tensile Strength

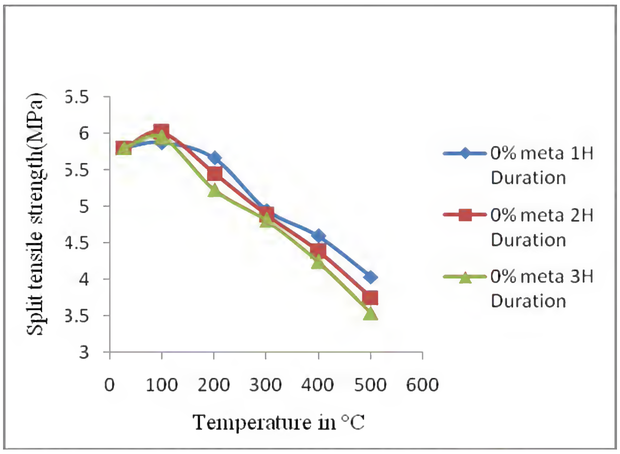

Figure 7: 28 Days Split Tensile Strength of Concrete (%) vs Exposed Temperature (°C) of 0% MKC

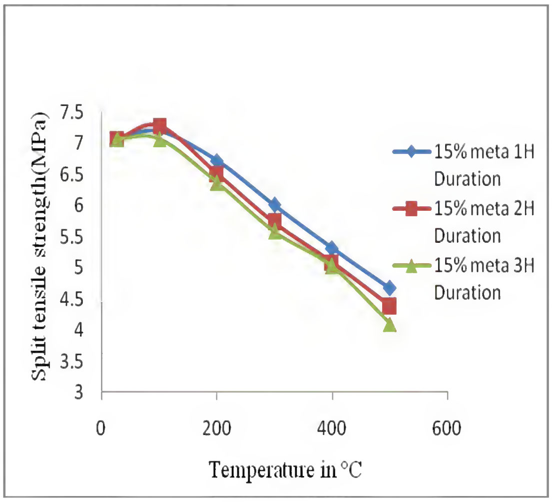

Figure 8: 28 Days Split Tensile Strength of Concrete (%) vs Exposed Temperature (°C) of 15% MKC

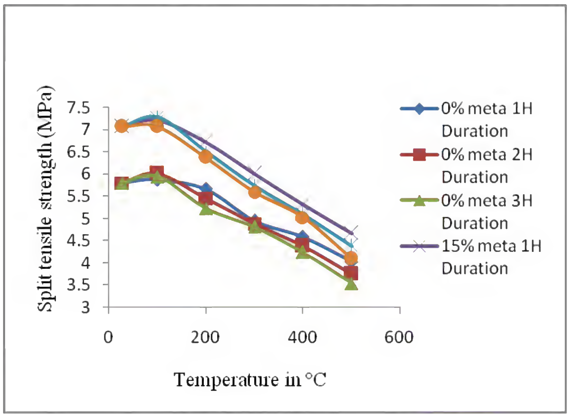

Figure 9: 28 Days Split Tensile Strength of Concrete (%) vs Exposed Temperature (°C) of 0% and 15% MKC

From the above graphs, it is observed that the split tensile strength increases at 100°C temperature when compared to the strength obtained at normal room temperature for 0% and 15% replacement of cement with MK. The increase in split tensile strength associated with the increase in temperature is attributed to the increase in the surface forces between gel particles (Vander wall forces) due to the removal of moisture content.

Flexural Strength

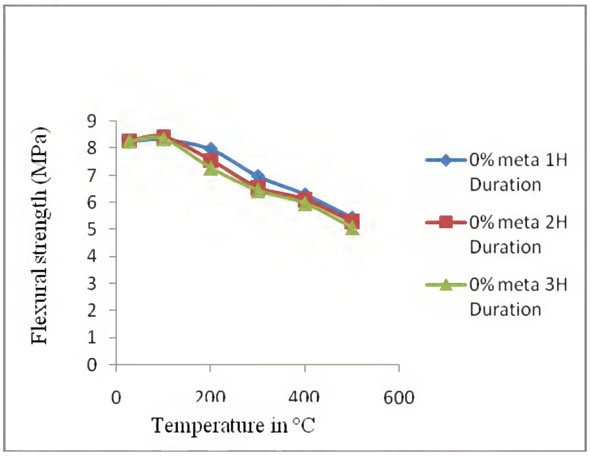

Figure 10: 28 Days Flexural Strength of Concrete (%) vs Exposed Temperature (°C) of 0% MKC

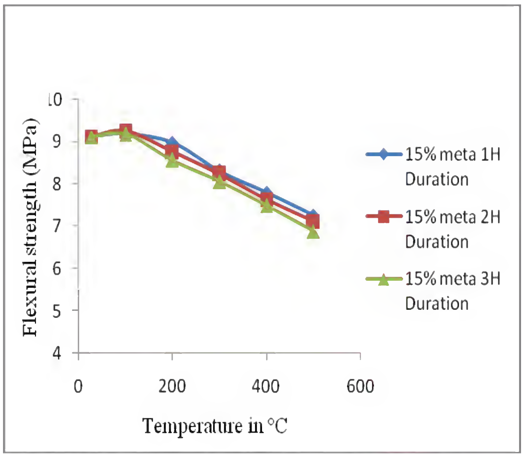

Figure 11: 28 Days Flexural Strength of Concrete (%) vs Exposed Temperature (°C) of 15% MKC

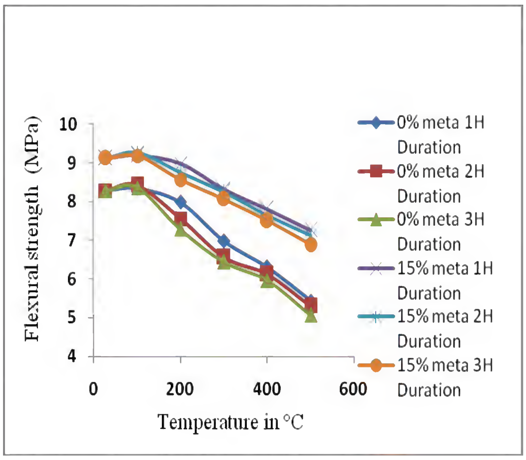

Figure 12: 28 Days Flexural Strength of Concrete (%) vs Exposed Temperature (°C) of 0% and 15%MKC

From the above graphs, it is observed that the flexural strength increases at 100°C temperature when compared to the strength obtained at normal room temperature for 0% and 15% replacement of cement with MK. The increase in flexural strength associated with the increase in temperature is attributed to the increase in the surface forces between gel particles (Vander wall forces) due to the removal of moisture content.

Stress-Strain Behavior

The stress-strain behavior of cylinder specimens for 0% and 15% replacement of cement with metakaolin, cured for 28 days age and subjected to elevated temperature from 100 to 500°C apart from room temperature were as shown below. The various graphs plotted are as shown below.

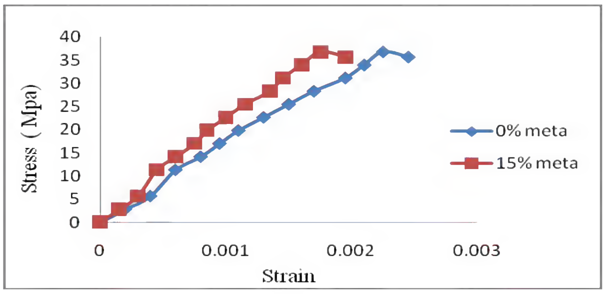

Figure 13: Stress-Strain Curve of Concrete at Room Temperature

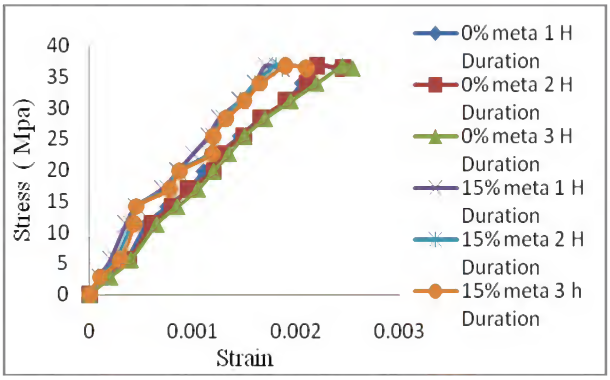

Figure 14: Stress-Strain Curve of Concrete Exposed to 100°c for Different Exposure Durations

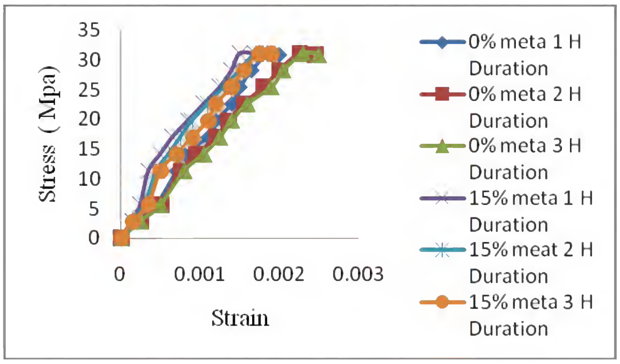

Figure 15: Stress-Strain Curve of Concrete Exposed to 200°c for Different Exposure Durations

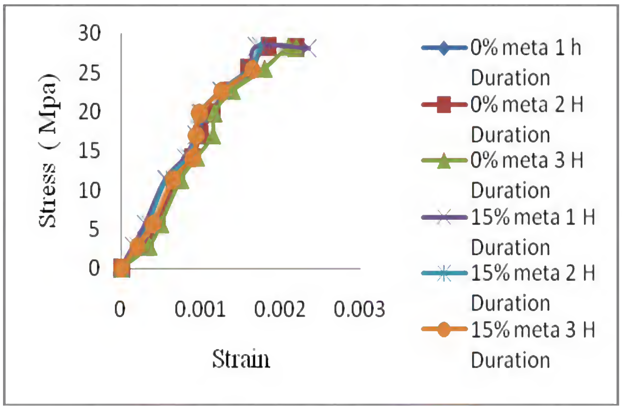

Figure 16: Stress-Strain Curve of Concrete Exposed to 300°c for Different Exposure Durations

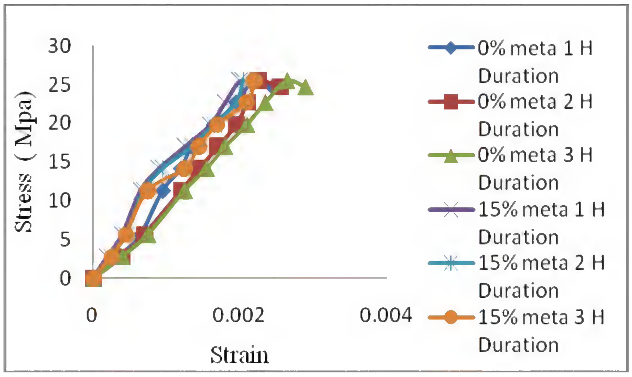

Figure 17: Stress-Strain Curve of Concrete Exposed to 400°c for Different Exposure Durations

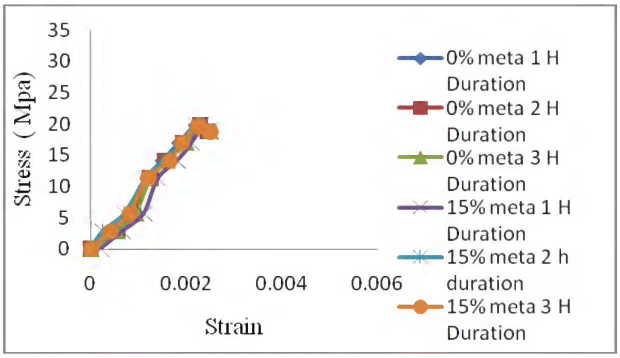

Figure 18: Stress-Strain Curve of Concrete Exposed to 500°c for Different Exposure Durations

From the above figures, the test results show that the tensile strength and peak strain increase with increasing metakaolin content whereas the tensile elastic modulus shows only small changes. The descending area of over peak stress is improved when 15% of cement is replaced by metakaolin. Also, the bend strength and compressive strength increase with increasing metakaolin content. The compressive elasticity modulus of concrete shows a small increase with increasing metakaolin replacement. The compressive strength increases substantially at early ages, and there is also higher long-term strength. Therefore, the metakaolin is a very efficient strength-enhancing addition.

CONCLUSIONS

Based on the experimental investigations carried out, the following conclusions are made.

- The compressive strength, flexural strength and split tensile strength of normal concrete and concrete with Metakaolin as partial replacement are compared and observed that the strength of the normal concrete is slightly lower than the Metakaolin replaced concrete.
- Among the various replacements, the concrete with 15% Metakaolin replaced cement shows good compressive strength than the other percentages.
- The strength of concrete increases at 100°C temperature and thereafter it starts decreasing as the temperature increases. This may be due to very dense pore structure of Metakaolin which enhanced the buildup of vapour pressure upon heating and resulted in spalling and cracking.
- The strength of concrete decreases with increase in time duration of samples kept in furnace. The strength obtained by the samples kept for 3 hours showed lesser strength than the samples kept for 1 hour at same temperature.
- The split tensile strength of concrete is increased when cement is replaced with Metakaolin. The split tensile strength is maximum at 15%of replacement.
- The flexural strength of concrete is increased when cement is replaced with Metakaolin. The flexural strength is maximum at 15%of replacement.
- The compressive strength of concrete showed better result at 15% replacement of MK for 0.5% and 1% HCL and H_2So_4 at the age of 28days of strength.
- The effect of HCL on strength of the Metakaolin concrete is lower than the effect of H_2SO_4.

- The benefit of using Metakaolin is to increase the pozzolanic action so as to prevent the corrosion activity of concrete in coastal areas.

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